

## Marine Boundary-Layer Clouds and Their Representation in a Climate Model

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The marine boundary layer is the bottom 500 to 2,000 m of the atmosphere over oceans. Because of the availability of heat and moisture, clouds often form in this shallow and turbulent layer for a long lasting period, and cover extensive areas. Their existence has important influences on Earth's climate for the following reasons. First, these clouds are highly reflective for solar radiation compared to their underlying ocean surfaces, so they drastically reduce the amount of solar radiation absorbed by the Earth. In the meantime, the emitted infrared radiation from these clouds to space are not much different from that from the ocean surfaces, since the cloud-top absolute temperatures are not significantly lower than those of the surfaces due to the low altitude of the clouds. As a result, these clouds reduce the total radiation energy received by the surfaces, which suggests that they tend to provide an overall cooling effect to the planet. In addition, these clouds are intimately involved in regulating moisture fluxes from the oceans, which are the major moisture source for the atmosphere. Thus, marine boundary layer clouds are important components of the climate and should be realistically represented in a climate model. However, this representation remains one of most difficult and unsolved problems, since the computer models cannot explicitly resolve the phenomena with the scales less than their grid length (several hundred kilometers) due to the limited computer power. More importantly, our knowledge of the physical processes operating in the clouds are far from complete, which makes impossible a realistic representation of the clouds in the

current climate models. In this research, we have focused on the following issues.

### Understanding the Interaction Between Shallow Cumulus and Stratiform Clouds

Observations from the recent field experiment, Atlantic stratocumulus transition experiment (ASTEX) showed that cumulus and stratocumulus clouds often coexist over large areas of the Atlantic Ocean. Thus, it is important to understand how the cloud system maintains. We used a two-dimensional numerical model that can explicitly resolve turbulent eddies in the boundary layer for this study. The model results indicate a strong mass detrainment from the cumulus to stratiform clouds, suggesting the importance of cumulus clouds in maintaining the stratiform clouds. It has been found from budget analysis that although the cumulus updrafts occupy only 1 percent of the domain, it contributes significantly to the turbulent fluxes. In addition, the horizontal transport of liquid water from cumulus updrafts to stratiform clouds is significant compared with the vertical turbulent transport in the stratiform clouds region. These results suggest that one needs to explicitly include the contribution from cumulus convection in the representation of large area of marine boundary-layer clouds.

### Effects of the Microphysics on the Cloud Optical Properties

It has long been recognized that an increase in cloud condensation nuclei (CCN) concentration number leads to an increase in the cloud albedo provided the liquid water content does not change, which is so-called Twomey effect. The assumption for this hypothesis is that there is no interaction between CCN change and cloud dynamics, which may be termed as noninteractive condition. However, when CCN number increases, the absorption of thin clouds increases, which will tend to reduce cloud liquid water by cutting off the moisture supply from below. This results in negative feedback from the cloud absorption to the albedo, which may be termed an interactive condition. To evaluate the feedback, we

used the same two-dimensional model to simulate diurnal variation of marine boundary layer clouds with two different cloud droplet numbers,  $50/\text{cm}^3$  and  $150/\text{cm}^3$ . The model calculation reveals that when CCN number increases, the simulated albedo increases. However, since liquid water content decreases resulting from the increase of the solar absorption, the cloud albedo does not increase as much as it would if no interaction between CCN and the cloud dynamics is allowed. The relative decrease due to the absorption feedback is between 0 and 20 percent, with the maximum decrease just after noon local time. The daily average decrease is about 5 percent. Current research is focusing on the following questions:

- Is it likely that a realistic increase in CCN number eliminates all the clouds?
- Is the decrease in the cloud albedo due to the cloud absorption important to the climate change problem?

These questions will be addressed using detailed models of atmospheric processes, and comparing results with observations and theory. Results will be used to improve the parameterization of these processes in global climate models.

Wang, S.: "Defining Marine Boundary-Layer Clouds With a Prognostic Scheme." *Monthly Weather Review*, vol. 124, pp. 1617-1833, 1996.

Wang, S.: "A Prognostic Approach of Parameterizing Marine Boundary-Layer Clouds." Abstracts in AGU fall meeting, December 15-20, San Francisco, CA 1996.

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**Biographical Sketch:** Dr. Franklin Robertson, (Ph.D., Purdue University, 1981), leads the Climate Diagnostics and Modeling Group in studying water and its

influence on the atmosphere and climate dynamics. He is involved in validating clouds and their representation in climate models. Robertson serves as the lead MSFC investigator on a joint EOS interdisciplinary investigation “The Global Water Cycle: Extension Across the Earth Sciences,” conducted jointly with Pennsylvania State University. 